CHAPTER 5
QUALIFICATION ASSURANCE

The qualification assurance topics of hardware and software quality assurance, instrumentation and calibration, plans and reports approval, test witnessing, test facility validation, simulation validation, testability, test-analyze-and-fix, procurement specifications, make or buy planning, special tooling, standardization program, and producibility are addressed.

5-1 INTRODUCTION

This chapter introduces and explains the aspects of hardware and software quality assurance and their relationships to the airworthiness qualification process. Common elements of the quality assurance program are the tasks of determining, ensuring, documenting, and maintaining contractual specification compliance. The objectives of qualification assurance are to provide a true and factual assessment confirming critical system characteristics and to provide adequate information and controls in order to duplicate the items in the required quantities and have each possess the same critical characteristics as the items that underwent the original qualification process. Proper application of these considerations allows smooth transition from development to production with minimal effort or duplication of activities.

5-2 HARDWARE QUALITY ASSURANCE PROGRAM

The objectives of a hardware quality assurance program are to ensure that contractor-developed and -produced hardware items meet specification requirements. The program applies to all activities conducted under the contract. The Hardware Quality Assurance Program (HQAP) complements the objectives of the airworthiness qualification program. Determination of safe performance capability and operating limits for production air vehicles by airworthiness qualification is dependent on the ability of hardware quality assurance to duplicate the critical characteristics of the qualified article in production units. The program should be conducted in a manner that assures adequate quality throughout all areas of contract performance, such as manufacturing, processing, assembly, inspection, test, packaging and shipping.[*] All supplies and services under the contract, whether manufactured or performed in the contractor's plant or at any other location, should be controlled by the contractor by means to be defined by the contractor. In general, management standards should not be specified in Government solicitations.

The quality program, including procedures, processes, and product, should be documented by the contractor and subject to review by the Government.

5-2.1 QUALITY ASSURANCE PROGRAM ELEMENTS

Table 5-1 provides a list and description of typical elements of quality

[*]American Society of Quality Control (ASQC) Q9000 series standards (Refs. 1 through 5) and statistical process control rather than inspection and test are favored for future contracts. An advanced quality system (AQS), such as "Design for Six-Sigma Manufacturability", should be considered. Therefore, ASQC Q9000 series standards (Refs. 1 through 5) and other advanced quality systems may be substituted for the quality system described in this chapter. Six-Sigma Manufacturability is an advanced quality system, which differs from a traditional quality system by emphasizing prevention of defects rather than after-the-fact detection of defects.

TABLE 5-1. TYPICAL QUALITY ASSURANCE PROGRAM ELEMENTS

ELEMENT	DESCRIPTION
Quality Program Management	Organization Initial quality planning Work instructions Records Corrective action Costs related to quality
Facilities and Standards	Drawings, documentation, and changes Measuring and testing equipment Production tooling Inspection equipment Advanced metrology and requirements
Control of Purchases	Responsibility Supplier control Purchasing Data
Manufacturing Control	Materials and materials control Production processing and fabrication Completed item inspection and testing Handling, storage, and delivery Nonconforming material Statistical quality control and analysis Indication of inspection status
Coordinated Government and Contractor Actions	Government inspection at subcontractor or vendor facilities Government property

assurance. Contractors should be encouraged to propose commercial means to satisfy these elements.

The quality program management element prescribes typical means for effective management of the quality function. The organization and methods used for the quality function are prescribed by the contractor. Typically these are determined through initial quality planning. Early in the contract, the contractor conducts a complete review of contract requirements to determine the needs for special controls, processes, test equipment, fixtures, tooling, and skills required to assure product quality. Work instructions often provide the criteria needed to perform the work functions and to supervise, inspect, and manage work. Records are usually used to document the results of inspections and tests and indicate the acceptability of work or products and the action taken in connection with deficiencies. Corrective actions result from the discovery of situations that could result in delivery of defective supplies, services, technical data, standards, or other elements of contract performance and could create excessive losses, delays, or cost. The final aspect of quality management could include maintenance and use of quality cost data.

The facilities and standards element typically deals with establishing and maintaining baseline information against which product performance can be compared. Procedures should be established to assure the adequacy, completeness, and currentness of

drawings and related technical data. Inspection and test equipment should be calibrated routinely to ensure that it meets the requirements for accuracy, repeatability, and traceability. Accuracy standards and inspection criteria should also be established for production tooling that is used as inspection media.

The control of purchases element typically addresses the need to ensure that supplies and services procured by a contractor from his vendors and suppliers conform to contract requirements. It should be the contractor's responsibility to ensure that qualified suppliers are selected, that quality requirements are transmitted to the suppliers, that adequacy of procured items is evaluated, and that provisions for early information feedback and correction of nonconformances are established. In the proposal the contractor should be required to identify the means by which these responsibilities will be satisfied.

The manufacturing control element deals with incoming inspection of material, production processing and fabrication, handling, storage and delivery, control of nonconforming material, statistical quality control, and indication of inspection status. Receiving inspections assess the acceptability of incoming material. In the proposal the contractor should be required to identify the means by which the needed controls will be satisfied.

The coordinated Government and contractor actions element addresses Government inspection at subcontractor or vendor facilities and the procedures for Government-furnished material. To assist the Government representative at the contractor's facility, the Government may inspect supplies or services at their source. When material is furnished by the Government, the contract should establish procedures to examine, inspect, test, and identify the material.

5-2.2 QUALITY ASSURANCE PROGRAM INCORPORATION

The contractors should be required to identify in their proposals the applicable hardware quality assurance program and standards. The same requirements should be included in the Airworthiness Qualification Specification (AQS). Any unique requirements applicable to the program may also be addressed in the contract or AQS. If no requirement for a Quality Assurance Program exists in the contract, critical elements of the program should be specified in the AQS. These requirements should be sufficiently detailed to identify the required tasks clearly.

5-3 SOFTWARE QUALITY

The objectives Of a Software Quality Assurance Program should be to ensure that all software developed and produced by the contractor satisfy critical characteristics and meet performance requirements. The scope of the Software Quality Assurance Program applies to all activities performed under the contract and includes deliverable and nondeliverable software, embedded software, and software support. The Software Quality Assurance Program complements the objectives of the airworthiness qualification program. Determination of the safe performance capability and operating limits for production air vehicles by airworthiness qualification is dependent on the ability of software quality assurance to duplicate the critical characteristics of the qualified article in the production units. The critical characteristics of software include functions, logic, timing, and both human/software and hardware/software interfaces that influence operational control. Airworthiness degrades if operational control causes improper response to inputs, does not respond to inputs, or allows hazardous conditions to exist. The

contractor's software quality program should ensure the quality of

1. Deliverable software and its documentation
2. The processes used to produce deliverable software
3. Nondeliverable software.

Contractors should be required to define in their proposals and specifications the means by which they will satisfy these objectives. Ultimately, the contractor should be responsible for quality and performance. Several related commercial standardization documents are ASQC Q9001, *Quality Systems—Model for Quality Assurance in Design, Development, Production, and Servicing,* (Ref. 2) and IEEE STD 1298/SAA 3563.1, *Software Quality Management System,* (Ref. 6).

5-3.1 SOFTWARE QUALITY ASSURANCE PROGRAM ELEMENTS

Table 5-2 identifies and describes typical elements of a Software Quality Assurance Program. The contractor(s) should be encouraged to propose commercial means to satisfy these elements.

The first element of a Software Quality Assurance Program relates to Evaluation of Software. This could be achieved through ongoing evaluations of all software to assure that

1. The software complies with the contract requirements, and emphasis is placed on reliability and software system safety.
2. The software adheres to the overall integrated plan.

The Evaluation of Software Documentation element could entail an evaluation of the software portion of the integrated plan to ensure it complies with the contract, with other software plans, and with system-level requirements. It could include the evaluation of other software documentation to ensure that each document adheres to the required format and that each document complies with the contract.

The Evaluation of the Processes Used in Software Development element could include an ongoing evaluation of software management, evaluation of software engineering, evaluation of software system safety, evaluation of software qualification, evaluation of software configuration management, evaluation of software corrective actions, evaluation of documentation and media distribution, evaluation of storage, handling, and delivery, and evaluation of other processes used in software development.

The Evaluation of the Software Development Library element could be accomplished by ensuring that

1. The library and its operation comply with the contract and adhere to the software plans
2. The most recent authorized version of materials under configuration control is clearly identified and is the one routinely available from the library
3. The previous version of materials under configuration control is clearly identified and controlled to provide an audit trail that permits reconstruction of all changes made to each configuration item.

The Evaluation of Nondevelopmental Software element could be accomplished by assuring that

1. Objective evidence exists prior to its incorporation that it performs its required functions reliably and safely.
2. It was placed under internal configuration control prior to its incorporation.
3. The data rights provisions are consistent with the contract.

The Evaluation of Nondeliverable Software element could be accomplished by

TABLE 5-2. TYPICAL SOFTWARE QUALITY ASSURANCE PROGRAM ELEMENTS

ELEMENT	DESCRIPTION
Evaluation of Software	Assurance that Software bears no adverse system safety impact. Software complies with contract. Software adheres to software plans.
Evaluation of Software Documentation	Evaluation of software plans Software plan compliance with contract Software plan consistency with other software plans and with system-level plans
Evaluation of Processes Used in Software Development	Evaluation of Software management Software engineering Software system safety Software qualification Software configuration management Software corrective actions Documentation and media distribution Storage, handling, and delivery Other processes used in software development
Evaluation of the Software Development Library	Assurance that Library and operation comply with the contract and plans. Most recent authorized version of materials under configuration control are identified and available. Previous versions of materials under configuration control are identified for audit trail purposes.
Evaluation of Nondevelopmental Software	Assurance that Nondevelopmental software performs required func-tions reliably and safely. Nondevelopmental software was placed under internal configuration control prior to use. Data rights provisions are consistent with contract.
Evaluation of Nondeliverable Software	Assurance that Software performs required functions. Software was placed under internal configuration con-trol prior to use.
Evaluation of Deliverable Elements of the Software Engineering and Test Environments	Assurance that deliverable elements Comply with contract and software plans Perform required functions reliably and safely Place under configuration control prior to use Data right provisions are consistent with contract
Evaluation of Subcontractor Management	Assurance that Subcontractor-developed software and documentation satisfy prime contract requirement. Baseline requirements for subcontractor are estab-lished and maintained. Software quality program requirements are imposed on subcontractor. Access for contractor review at subcontractor's facility. Contracting agency has right to review subcontractor.

TABLE 5-2. (Cont'd)

ELEMENT	DESCRIPTION
Evaluations Associated With Acceptance Inspection and Preparation for Delivery	Assurance that All required software products are available for review. All required procedures have been performed. All deliverables have been updated to reflect all ap-proved changes.
Participation in Formal Reviews and Audits	Assurance that all review products are available and that all required preparations have been made. Presentation of evaluation of status and quality of each development product. Assurance that all action items resulting from review have been performed.

evaluation of each nondeliverable software item used in the automated manufacturing of deliverable hardware or in the qualification or acceptance of deliverable software, or hardware could be evaluated to ensure that

1. Objective evidence exists prior to its intended use that it performs the required functions.
2. It was placed under internal configuration control prior to its use.

The Evaluation of Deliverable Elements of the Software Engineering and Test Environments element could be accomplished by the contractor's evaluation of each deliverable element of the software engineering and test environment to assure that

1. It complies with the contract and adheres to the software plans.
2. Objective evidence exists prior to its use that it performs required functions.
3. It was placed under internal configuration control prior to its use.
4. The data rights provisions are consistent with the contract.

The Evaluation of Subcontractor Management element could entail the contractor's evaluation of all subcontractor activity to assure that

1. All subcontractor-developed software and related documentation deliverable to the contracting agency satisfy the prime contract requirements.
2. A set of baseline requirements is established and maintained for the software to be developed by the subcontractor.
3. Applicable software quality program requirements are included or referenced in the subcontract or purchase documents for the subcontractor.
4. Access is available for contractor reviews at subcontractor and vendor facilities.
5. The contracting agency has the right to review all software products and activities required by the subcontract at the subcontractor facilities to determine compliance with the subcontract.

The Evaluations Associated With Acceptance Inspection and Preparation for Delivery element could be accomplished by the contractor to assure that

1. All required software products are available and ready for contracting agency inspection.
2. All required procedures have been performed and evidence of satisfactory completion of these procedures is available for contracting agency inspection.
3. All deliverable software and documentation have been updated to reflect all changes approved by the contracting agency and scheduled for inclusion.

The final element, Participation in Formal Reviews and Audits, could require that

1. Prior to each review and audit, the contractor assures that all required products will be available and ready for contracting agency review and that all required preparations have been made.

2. At each formal review and audit the contractor presents an evaluation of the status and quality of each of the development products reviewed.

3. Following each formal review and audit, the contractor assures that all software-related action items assigned to the contractor have been performed.

5-3.2 SOFTWARE QUALITY ASSURANCE PROGRAM INCORPORATION

Just as with Hardware Quality Assurance Program requirements, Software Quality Assurance Program requirements may be specified by reference in the contract, system specification, or AQS. Any unique requirements applicable to the program may also be addressed in the contract, system specification, or AQS. If no requirement for a Quality Assurance Program exists in the contract, critical elements of the program should be specified in the AQS

5-4 INSTRUMENTATION AND CALIBRATION FOR TESTING

Instrumentation is the means by which physical variables are measured. It is comprised of sensors and data transmitting, receiving, displaying and recording equipment. Calibration procedures involve a comparison of the particular instrument with (1) a primary standard, (2) a secondary standard with a higher accuracy than the instrument being calibrated, or (3) a known input source. The objective of instrumentation and calibration is to collect evidence that a characteristic value is present under specified conditions. The presence of this value provides the basis for determining that a specification requirement has been met and therefore forms a basis for airworthiness qualification.

5-4.1 INSTRUMENTATION PLANS AND REVIEWS

A separate instrumentation plan should not be required by the PA; however, instrumentation requirements should be included in the contract and Airworthiness Qualification Specification. The contractor should be responsible for data reduction and analysis, which the PA should review and approve. The criteria for instrumentation selection includes tradeoffs between instrumentation cost, required accuracy, facility use and availability, and data reduction and processing requirements. The contractor's proposal should detail its data collection methods, proposed flight instrumentation equipment, data reduction and processing requirements, and the proposed data reduction facilities equipment. Also the proposal and system specification should address the extent to which built-in test equipment (BITE) onboard the air vehicle will be used as well as the requirements for external instrumentation. Differences in instrumentation requirements during various test phases should also be addressed.

Instrumentation reviews should be conducted when instrumentation issues are sufficiently complex to warrant direct interface between Government and contractor personnel. Such issues might involve the use of Government facilities or the requirement for highly specialized instrumentation. A thorough review of demonstration requirements is necessary to identify the parameters to be measured and the instrumentation methods to be used for measurement. An integral part of this review is identification of the accuracy requirements for measurements since these will drive the com-

plexity, sophistication, and cost of the instrumentation system.

5-4.2 FLIGHT TEST INSTRUMENTATION

Air vehicle flight test instrumentation typically records air vehicle attitudes, rates, accelerations, pitot-static data, temperatures, flow rates, and human-factors-related parameters. Typical instrumentation sensors include accelerometers, strain gages, temperature and pressure sensors, flow sensors, position sensors, vibration sensors, and audio- and video-sensing devices. In addition, instrumentation may be provided to record cockpit switch settings and flight crew activity. Output of electronic displays may be recorded for analysis of system performance. For onboard digital communication busses, bus monitoring devices monitor and record bus traffic. The monitoring may be selective, in which case only specific types of bus messages are monitored, or it may capture all bus activity.

Signals from sensors are passed through signal-conditioning circuits, such as amplifiers and filters, prior to recording. Recording may be performed onboard the air vehicle or on the ground with telemetry devices used to communicate the data from the air vehicle to the ground. Often, a combination of both recording methods is used. The recording medium may be either magnetic (tape or disk), solid-state (flash memory, random access memory (SRAM), erasable programmable read-only memory (EPROM)), or optical. Data may be recorded in either analog or digital formats. Digital recording allows the application of digital signal processing techniques, which greatly enhance the capability for later data reduction.

Data processing is the activity that turns raw data into results, which may be compared with performance requirements. Processing may take place in real time, i.e., as the data is being gathered, or it may be performed after the test. Real-time data processing has the advantage of providing immediate feedback on test progress and results and allows for a quick reaction to test progress. This advantage can greatly reduce the need for test time and facilities by allowing on-the-spot correction of problems or other intervention by test personnel during the test. Certain data reduction processing requirements may be so computationally intensive that they can be performed only after completion of the test.

It is essential that prior to the test the data collection and processing system be validated to ensure that valid results are generated. Validity of data is determined by comparing data processing results with independently generated or determined data.

5-4.3 RANGE INSTRUMENTATION

Range instrumentation includes time-, space-, and position-information sensors; transponders; and range-time receivers. Specialized range instruments are also used to determine air vehicle acoustic, optical, infrared, and radar signatures. Instrumented targets, both moving and stationary, are required to perform weapon system effectiveness testing. The instrumentation system should be able to provide time-tagged information relative to target position, velocity, and acceleration. Meteorological conditions at the target area, such as visibility conditions (which include both naturally occurring and man-made obscurants), temperature, precipitation conditions, and atmospheric attenuation at the specific wavelength of the sensors under test should be recorded. Instrumentation should also be provided that will allow determination of weapon impact or weapon miss distances in both the cross-range and downrange directions. For tests involving missiles, the missiles may also be instrumented.

5-4.4 CALIBRATION REQUIREMENTS

Calibration should be performed to ensure the accuracy of the instrumentation. The contractor should be required to establish and maintain a system to calibrate all measuring and test equipment used in the fulfillment of contractual requirements. The contractor should identify in its proposal the calibration standards to be used for performance of the contract. ISO 10012-1, *Quality Assurance Requirements for Measuring*, (Ref. 7) and ANSI Z540-1, *Laboratories, Calibration, and Measuring Test Equipment*, (Ref. 8) are considered satisfactory commercial standards, and there could be others. Measurement standards used by the contractor to calibrate measurement and test equipment should be traceable to a specific standard and have the accuracy, stability, range, and resolution required for its intended use. If targets are used for weapon system effectiveness testing and their specific condition at the time of the test is significant to the test outcome, these targets should be calibrated also. For example, if thermal bar pattern targets are used to test thermal imaging system performance characteristics, they should be calibrated so that target conditions at the time of the test are well understood. Similarly, if the test involves electromagnetic measurements, it is necessary to calibrate the test equipment to the electromagnetic environment at the time of the test in order to understand properly the environmental effects on test results.

5-5 APPROVAL OF PLANS AND REPORTS

Plans and reports undergo approval cycles internally within both the contractor's organization and the Government.

Internally the plan or report is prepared by the originating organization and signed off by those organizations or individuals having review or approval responsibility.

The contract data requirements list (CDRL) specifies the nature of the approval required for all data submittals including plans and reports. The objectives of the approval of the plans and reports are to

1. Ensure that the contractor submits those documents in accordance with the requirements of the contract

2. Ensure that the appropriate Government personnel can determine and document the contractor’s accomplishment of contractual requirements.

Generically, plans and reports submitted to the Government for approval are distributed within the Government to the appropriate engineering and program management personnel. They prepare their comments and submit them to the individual with primary technical responsibility for the subject matter covered by the plan or report. That individual collects Government inputs and consolidates them after resolving any potential conflicting comments. Plans and reports may be approved as submitted, approved subject to the incorporation of Government comments, or rejected if the document is not responsive to Government requirements. Government comments to plans and reports are forwarded to the contractor via the contractual channel. If the contractor is required to correct deficiencies identified in the plans and reports, the procuring agency typically will specify a required response time for their correction.

Usually, test plan and report preparation, coordination, and approval generate

many draft versions with errors and omissions. Thus controlled release of test plans and reports by a document control activity provides a source of known version(s) of the documents approved for use. This procedure assures that the correct tests are performed and that an accurate record of the test conducted and its results are available to document the qualification.

5-6 TEST WITNESSING

The test witness is responsible for reviewing the plans of test(s) and the contract requirements (system specifications, etc.) and for being familiar all aspects of the test(s) to be witnessed. As a Government representative, the test witness is responsible for verifying the contractor's test report. As early as possible, the witness should inform the test coordinator of any special requirements in the areas that follow (if applicable):

1. Specific documentation and data, e.g., plans, reports, and drawings, that will be used in witnessing activities
2. Special briefings unique to his areas of interest
3. Portion of the test to be witnessed.

The test witness should review and countersign the test report prepared by the contractor. This constitutes verification of the scope and details of the test and that the test was conducted with or without deviations from the Government-approved test plans. It does not necessarily indicate concurrence in the conclusions presented. The witness or observer should provide an evaluation of the test to the test coordinator and should also discuss any requirements for special witnessing reports with the coordinator.

A generic AQS requirement for test witnessing follows:

Based on the contractor's master test schedule, the procuring agency will designate those tests that require Government witnessing. Prior to any required test, survey, or demonstration and prior to component or subsystem disassembly following same, the test coordinator designated by the procuring activity shall be notified in sufficient time to witness the test or disassembly. If the test interpretation requires specific engineering knowledge, the test coordinator shall be notified by the contractor a minimum of five (5) working days prior to the test. No designated test will be conducted without the test coordinator or his representative being present. Deviation from these procedures is subject to case-by-case approval of the procuring activity.

The test coordinator should be responsible for ensuring that a qualified witness is present during the important phases of a test program. For tests that are considered a significant part of the qualification program, the test witness(es) generally should be provided by the procuring activity.

5-7 TEST FACILITY VALIDATION

The objective of test facility validation is to assure that the contractor's test facility is adequate for achieving its airworthiness qualification functions. The criteria used to establish a requirement for test facility validation depends on the extent to which the airworthiness qualification objectives are dependent on the adequacy of the test facility and the degree of previous use of the facility by the contractor for similar purposes.

Generally, a test facility may be validated by defining its intended function and showing evidence that it is properly equipped and staffed for that intended function. Equipment considerations should include test fixtures, stimulus capabilities, measurement capabilities, data pro-cessing capabilities, tools, support equipment, interface equipment, and suitability of the facility to conduct flight-test operations.

Staffing considerations should include appropriate engineering and technical personnel to set up, perform, and analyze test activities.

An example of a typical Airworthiness Qualification Specification (AQS) requirement for test facility validation follows:

"The contractor shall conduct a test facility validation for [name of test facility] for the purpose of providing objective evidence that the facility is suitable for achieving the airworthiness qualification objectives of [name of test]. The validation shall include a complete description of the facility to include intended uses, test fixture descriptions and capacities, stimulus capabilities, measurement capability, data processing capabilities, and interfacing equipment. The validation will also describe specific tests conducted to demonstrate that the facility is capable of producing valid results."

Types of facilities that may require validation include whirl towers, engine test facilities, wind tunnels, dynamic component integration facilities, electronic component integration facilities, and hardware/software integration facilities.

5-8 SIMULATION VALIDATION

Simulations and their role in the airworthiness qualification process are discussed in detail in Chapter 6. The objective of simulation validation is to show that the simulation adequately represents the system being modeled with respect to the critical characteristics under consideration by the simulation. The criteria used to establish simulation validation requirements depend on the extent to which the contractor intends to use simulation activities to fulfill airworthiness qualification objectives. For example, a simulation intended to be used to predict performance during the concept exploration phase will generally require less data to substantiate validation than if the simulation or model is intended to be used for or to replace qualification data.

Simulation validation requirements are also dependent on the degree of abstraction between the real-world item being modeled and the simulation. The greater the degree of abstraction, the greater the number and types of simplifying assumptions are made about the real world in order to consider only the most fundamental variables and their interactions.

Simulation validation requires exercising the simulation over as wide a range of possible conditions and the confirmation from independent data and analysis that the simulation yields valid results. Simulations used to predict design performance and used for qualification purposes may also require verification of model data versus measured data and may require accreditation by a third party.

Several different methods may be used to validate simulations. They include expert consensus, comparison with test data, peer review, and independent review.

A general simulation validation requirement for incorporation into an AQS is as follows:

"The contractor shall prepare a simulation validation for [name of simulation]. The validation shall describe the airworthiness objective to be accomplished by the simulation. It shall also describe the simplifying assumptions inherent in the simulation and their impact on results. The contractor shall provide a comparison of simulation data and independently obtained data to demonstrate that the simulation yields valid results."

5-9 TESTABILITY

Testability is a characteristic of design that allows the status—operable, inoperable, or degraded—of an item to be determined and the isolation of faults within the item to be performed in a timely manner. Testability may be achieved through the combination of external resources, such as automatic test equipment (ATE), and internal capability, such as self-diagnostics and built-in test (BIT).

MIL-STD-2165, *Testability Program for Systems and Equipments*, (Ref. 9) or an equivalent handbook, may be used as a guide to testability requirements (including BIT), testability analysis, prediction and evaluation, and preparation of testability documentation; however, the standard should not be specified or referenced in solicitations. Tasks described in this standard are intended to be tailored to the particular needs of the system or equipment acquisition program. Testability requirements should be based on mission needs and system performance requirements. Also testability requirements should be closely linked to logistic and maintainability performance requirements. The contractor should be required to identify in the proposal the means to be used to satisfy the testability requirements.

DARCOM-P 34-1, *Built-in-Test Design Guide*, (Ref. 10) presents the fundamentals of BIT, provides an overview of the different approaches and requirements available to the designer and the acquisition manager, and discusses standardized methods used to evaluate these different approaches.

5-9.1 GENERAL TESTABILITY FEATURES

Testability should be achieved through incorporation of appropriate design features to allow for fault detection and isolation. Such features should include functional grouping, separation of functions, and accessibility of test points. If the specific system components that provide a function are grouped together, the loss of that function should be readily attributed to the failure of the grouping providing that function. Generally, if the components providing the function are widely distributed throughout the system, isolation of the fault becomes much more complicated and ambiguous. If functions are separated, a component failure is likely to affect only one function rather than multiple functions. Again, this approach yields a more testable design. Ample test points should be provided throughout a system. These testability features provide benefits in both an operational environment and the course of the airworthiness qualification process by providing a means to identify system mission performance capability.

5-9.2 AUTOMATIC TEST EQUIPMENT (ATE)

The concept of ATE is to permit automatic test and diagnostic of equipment while minimizing manual test requirements. The objective of ATE testability is to ensure that an item (usually electronic in nature) can be tested outside the system in which it is installed by automatic test equipment. To accomplish this, the item should be able to accept stimulus from an outside source and provide the necessary response. By providing appropriate stimulus and analyzing the response, the ATE is able to determine the status of the item and, if the item is degraded or failed, isolate the failure to permit repair. The advantages of ATE testability over BIT are that it usually allows a greater number of parameters to be tested and results in a lower initial hardware cost because the test circuitry does not have to be included in every item produced. An ATE testability capability furthers the airworthiness qualification objectives by allowing determination that an item meets performance requirements at all

stages of development and use—during the development stage, when it is produced, after storage, and after repair.

5-9.3 SELF-DIAGNOSTICS AND BUILT-IN TEST (BIT)

Self-diagnostics and built-in test refer to the capability to determine the operational status of an item while installed in the system. BIT may be of a continuous nature or initiated by the operator or maintainer. Continuous, or on-line, BIT places demands on the system and should therefore be limited to immediate detection of critical functions. Operator- or maintainer-initiated, off-line, BIT is usually used for fault isolation purposes. Advantages of BIT capability over ATE testability include the fact that BIT allows instantaneous performance monitoring; eases the burden on the operator; reduces the requirements for shop facilities, equipment, and personnel; and generally reduces life cycle cost.

Properly designed and functioning BIT contributes to the objectives of the airworthiness qualification process by assuring that the system is performing acceptably during development, during operation, and after repair.

5-9.4 NONDESTRUCTIVE TEST AND EVALUATION (NDTE)

The objective of nondestructive test and evaluation is to determine the integrity of parts by measurement or inspection without damage or destruction. The test is intended to reveal conditions at or beneath the exterior surface of a part or material that cannot be evaluated solely by visual examination with or without magnification or by dimensional measurement. In general, NDTE should be used to determine the condition of materials, whereas BIT and ATE should be used to determine the condition and functionality of electronics. NDTE techniques include but are not limited to electromagnetic (eddy current) testing to inspect welds, measure coating thickness, and determine electrical conductivity; ultrasonic testing; ultrasonic contact inspection of weldments; radiographic inspections; ultrasonic adhesive bond testing; temper etch inspection; fluorescent penetrant methods; magnetic particle methods; and halogen leak detection methods.

The use of NDTE should be integrated into the design process to ensure that the materials, manufacturing techniques, and other design characteristics are compatible with the NDTE techniques used to monitor the integrity of flight-critical parts.

5-10 TEST-ANALYZE-FIX-TEST (TAFT)

The test-analyze-fix-test (TAFT) sometimes also referred to as “test-analyze-and-fix” (TAAF), is central to the qualification process. Airworthiness qualification is more than just testing and reporting the results, good or bad. The TAFT principles ensure that the qualification program not only uncovers deficiencies in a system but also provides a mechanism for identification and incorporation of fixes required to complete and pass qualification. TAFT requirements should be included in Airworthiness Qualification Plans (AQP) and Airworthiness Qualification Specifications.

A TAFT program identifies and corrects performance-related problems or deficiencies and reliability problems. Integral to TAFT is a closed-loop data collection system that captures the circumstances of occurrence of the problem or deficiency. The appropriate contractor organization is assigned the responsibility to identify the cause of the problem or deficiency and to develop the necessary corrective action. Upon incorporation of the corrective action, the performance of the system is monitored to ensure that the problem does not recur.

Periodic reporting to the Government provides the procuring activity with visibility of development status and potential problem areas. TAFT is applicable throughout all phases of the airworthiness qualification effort from initial design model activities through component and subsystem qualification to system-level qualification efforts. The effectiveness of TAFT is enhanced by ensuring that test conditions and operating profiles reflect intended operating conditions to the maximum extent possible.

Ideally, corrective actions should be incorporated as soon as they are developed and available. This should allow the best opportunity to determine that the corrective action has (1) fixed the problem that necessitated the action and (2) not introduced any unintended problems or deficiencies. Schedule constraints, however, often dictate that test activities continue even though known fixes have not yet been incorporated. This is usually the result of insufficient test hardware or other test resources. From a cost and management standpoint it may be desirable to incorporate fixes in blocks as opposed to one at a time. This, however, could lead to a significant lag between fix identification and fix incorporation. Too long a lag could greatly reduce the effectiveness and benefits of the TAFT. Specific contractual requirements should be established to limit the amount of lag in fix incorporation. The criteria used to determine how quickly a fix should be incorporated include the severity or criticality of the problem, the extent of effort required to identify the cause, the extent of effort required to develop the corrective action, the extent of effort required to incorporate the corrective action, and the impact of incorporating the corrective action into other ongoing test activities.

5-11 DEFENSE SPECIFICATIONS, STANDARDS, AND HANDBOOKS

The Department of Defense (DoD) no longer specifies detailed military process specifications and standards in its contracts and solicitations without an appropriate waiver. It is DoD policy to use international and domestic non-Government specifications and standards to the maximum extent possible instead of federal and military specifications and standards. Perfor-mance specifications should be developed in preference to detailed specifications. For any pro-cess, practice, or method that is described by a non-Government standard used by commercial firms, DoD activities should use the non-Government standard instead of developing or revising a DoD standard. If a suitable non-Government standard is not available, DoD activities should consider working with industry on a technical committee to develop a new standard or revise an existing non-Government standard. Handbooks have replaced a number of standards, but they should be used only as guides. Additional information concerning specifications, standards, and handbooks is in the subparagraphs that follow.

5-11.1 SPECIFICATIONS

MIL-STD-961, *Department of Defense Standard Practice for Defense Specifications*, (Ref. 12) establishes the format, content, and procedure for the preparation of performance specifications and associated documents prepared either by Government activities or under contract.

Requirements in performance specifications should describe what is required and the form, fit, or function of the item. Interface requirements that are not adequately defined by form, fit, and function should also be included. Performance specifications should not describe how a requirement is to be achieved, require the use of specific materials or parts, or give detailed design or construction requirements beyond those needed to ensure interchange-

ability with existing items. For a general specification to be designated a "performance specification", the requirements in its associated specification, specification sheets, or MS sheets should also be stated as performance requirements.

"Detailed specifications" may consist of all detailed requirements or a blend of perfor-mance and detailed requirements. To the greatest extent possible, detailed specifications should be in terms of performance. They should specify materials, design or construction requirements, or "how to" requirements only to the extent necessary to ensure the adequacy, safety, and interchangeability of the item being acquired.

5-11.2 STANDARDS

MIL-STD-962, *Department of Defense Standard Practice for Defense Standards and Handbooks*, (Ref. 11) provides definitions and format and content direction. DoD standards should be prepared only when it is necessary to capture military-unique requirements. Non-Government standards should be used to describe commercial or industry practices, processes, and methods. There are five types of DoD-prepared standards: interface standards, standard practices, test method standards, manufacturing process standards, and design criteria standards.

DoD interface standards should be developed to specify the physical, functional, or military operational environment interface characteristics of systems, subsystems, equipments, assemblies, components, items, or parts to permit interchangeability, interconnection, interoperability, compatibility, or communications. Many, if not most, standards have interface elements. To be designated an interface standard, establishing mandatory interface requirements should be the primary function of the document. If interface criteria are just one of many design criteria requirements, developing a design criteria standard should be considered.

DoD design criteria standards should be developed to specify military-unique design or functional criteria that must be adhered to during development of systems, subsystems, equipments, assemblies, components, items, or parts. These design criteria are not primarily related to requirements that affect interchangeability, interoperability, interconnection, compatibility, or communications. Adherence to these design criteria standards, however, will affect the manufacturing of a product. Some examples include military-unique design selection, nuclear blast protection, safety requirements, and human factors requirements.

DoD standard practices should be developed when it is necessary to specify procedures on how to conduct nonmanufacturing functions. Standard practices should be developed only for services that, at least some of the time, are obtained via contract from private sector firms. Standard practices should not be used if non-Government standards are the typical commercial vehicle used to procure a particular type of service.

Test method standards should be developed to specify specific test methods, procedures, or protocols. Military test method standards should reflect test methods that are unique to the DoD such as tests for the high levels of shock encountered in the landing of an air vehicle on an aircraft carrier. A DoD test method standard should be developed only if it reflects a military-unique requirement.

The DoD strongly discourages development of manufacturing process standards. The role for DoD process standards is limited to situations in which the DoD alone has the technological expertise to specify a military-unique process.

The DoD also strongly discourages development of management process standards. It is not the policy of the DoD to

create standard management approaches across all programs and all contractors. Contractors should be allowed the flexibility to manage programs in innovative ways that can improve quality, reduce costs, and introduce the latest technological advances.

5-11.3 HANDBOOKS

MIL-STD-962, *Department of Defense Standard Practice for Defense Standards and Handbooks*, (Ref. 11) provides definitions and format and content direction for handbooks prepared either by Government activities or under contract. Handbooks are developed following the processes described for standardization documents in DoD 4120.3-M, *Defense Standardization Program, Policies, and Procedures*, (Ref. 13) except there will not be any interim handbooks. The procuring activity (PA) should not cite handbooks as requirements in solicitations, contracts, or any type of technical document. Rather than develop mandatory standards that require a single approach when other approaches may also be acceptable, a handbook offers an opportunity to preserve institutional memory and offer solutions that have worked without mandating those solutions. Handbooks are good for providing lessons learned; classifying items, materials, or processes; defining terms; listing abbreviations or acronyms; providing interpretation; offering different technical options; and any other type of guidance information. If a handbook is cited as a requirement, contractors may disregard the requirement and interpret the contents as guidance only.

5-12 MAKE OR BUY PLAN

Make or buy plans are not required during research and development. Also these plans are not required if prototypes or hardware is involved, but no significant follow-on production under the same contract is anticipated. Further, make or buy decisions are primarily affordability and cost related. As such, make or buy plans and decisions do not affect airworthiness qualification decisions. It is primarily a program issue. See FAR Subpart 15.7, *Make or Buy Programs*, (Ref. 14) and DFAR Subpart 215.7, *Make or Buy Programs*, (Ref. 15).

5-13 SPECIAL TOOLING

One of the critical functions in assuring repeatability in the manufacturing and assembly cycle is tool control. The tools used in the manufacturing and fabrication cycle must have the capacity to reproduce each detail, subassembly, and assembly in accordance with the accepted design configuration. As engineering design changes are proposed, they should be reviewed for their impact on applicable tooling. The quality assurance function should be intimately involved in establishing the need for, proofing, and controlling special tooling.

Detailed specifications covering the fabrication of tools to be employed in the manufacture and assembly of an air vehicle should be provided. In addition, detailed process instructions for the use of the tools in production, for recheck and/or recalibration, and for inspection of the parts produced by the tool should be developed.

Master tool control normally is the only practical method of coordinating tooling and ensuring interchangeability. The accuracy and ease with which mating assemblies fit or are individually interchangeable are dependent on the control of size, shape, and matching interface conditions at attachment points.

A program of inspection and tool verification to be used in the manufacture of the contract end-item should be developed.

5-14 STANDARDIZATION PROGRAM

A properly conducted standardization program facilitates the achievement of airworthiness qualification and quality as-

surance program by imposing a structured method for minimizing the variety of parts used in a new design. The objectives of the program are to

1. Maximize use of standard parts, materials, and processes in order to lower cost, to reduce downtime, and to facilitate interchangeability
2. Maximize repetitive use of features and items
3. Maximize use of common publications, manuals, training aids, and materials
4. Provide the documentation for future reuse of the innovations initially used under the current contract
5. Provide for common usage of equipment, parts, and materials in order to promote commonality among weapon systems.

MIL-HDBK-402, *Guidelines for the Implementation of the DoD Parts Control Program*, (Ref. 16) is a guide intended for use by military departments and agencies and associated contractors. However, unless otherwise specified in the contract, parts control and parts standardization should be conducted by using best commercial practices, industry standards, and the contractor's policies and procedures. This should apply to mechanical, electrical, and electronic parts. The contractor should be required to identify in the proposal and specification the applicable commercial practices, standards, policies, and procedures that will be followed to accomplish these objectives.

5-15 PRODUCIBILITY

Producibility is defined as the repeatability and relative ease of producing an item or system. It is governed by the characteristics and features of a design that enable economical fabrication, assembly, inspection, and testing using available production techniques. The basic concept of producibility is to ensure that there is a coordinated effort between design engineering and manufacturing engineering to create a functional design that can be easily and economically fabricated. This activity requires tradeoffs among life cycle costs, performance, reliability, and producibility. The scope of producibility is variable and evolutionary based on the stage of the qualification program. A major program in the conceptual stage should consider system performance requirements while contemplating broad areas of producibility on a general scale, i.e., basically envisioning global manufacturing capabilities. During the next phase, integrated design and producibility considerations should be narrower in scope and greater in number than during the preceding phase and should create opportunities to achieve significant cost and schedule benefits as the hardware design evolves and before the design becomes too fixed to be altered economically. Finally, a major program in the full-scale development phase will emphasize specific producibility studies in far greater depth and basically build on the studies, decisions, and concurrent design and producibility activities that have gone before. Proper and early consideration of producibility principles reduce the risks associated with the transition from development to production. Addressing producibility as an integral part of the design process minimizes the chances of introducing problems associated with the transition from a prototype manufacturing environment to a production environment and thereby ensures a qualified prototype design can be built in production quantities using production methods. The contractor should be required to define in the proposal and specifications the means by which specified levels of producibility will be assured and demonstrated. A separate plan should not be required. The procuring activity should include producibility performance requirements in the contract. The air vehicle contractor (AC) should be required to define in the proposal

the means by which producibility will be assured. MIL-HDBK-727, *Design Guidance for Producibility*,(Ref. 17) provides an exposition of the factors that determine whether or not an item is acceptable from a producibility point of view. Actual examples of good and bad producibility practices are provided. The interrelationships of the producibility functions with the design process and development process functions are discussed. Tools and techniques useful in the producibility function and used by the producibility engineer are described and illustrated. Common producibility considerations are discussed. Specific considerations for metal components, plastic components, composite components, mechanical assemblies, electronics, and other items are discussed.

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3. ASQC Q9002, *Quality Systems—Model for Quality Assurance in Production, Installation, and Servicing*, American Society of Quality Control, Milwaukee, WI, 18 July 1994.
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9. MIL-STD-2165A, *Testability Program for Systems and Equipments*, 1 February 1993.
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